Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

In the Matter of	)	
	)	
Amendment of the Commission's Rules with Regard to Commercial Operations in the 3550-3650 MHz Band	)))	GN Docket No. 12-354

Reply Comments of Nokia Solutions and Networks US LLC

Brian Hendricks
Head of Technology Policy

Prakash Moorut
Spectrum Lead
North America

575 Herndon Parkway
Suite 200
Herndon, VA 20170

August 15, 2014

Nokia Solutions and Networks US LLC ("Nokia Networks") hereby respectfully submits these reply comments in response to the initial comments filed pursuant to the *Further Notice of Proposed Rulemaking* ("*3.5GHz Small Cells FNPRM*")[1] seeking comments on specific rules for a new Citizens Broadband Radio Service in the 3550-3650 MHz ("3.5 GHz") band.

Contents

I. INTRODUCTION AND SUMMARY .... - 2 -

II. NOKIA NETWORKS' SIMULATIONS OF RADAR INTERFERENCE TO LTE MACRO AND SMALL CELLS BASE STATIONS SUGGEST THAT THE PROPOSED EXCLUSION ZONES CAN BE FURTHER REDUCED .... - 5 -

A. Radar to LTE Macro BSs Interference Simulation Results .... - 6 -

B. Radar to LTE Small Cells BSs Interference Simulation Results .... - 7 -

III. CONCLUSION .... - 9 -

IV. APPENDIX - RADAR TO LTE MACRO AND SMALL CELLS BASE STATIONS INTERFERENCE SIMULATIONS ASSUMPTIONS .... - 10 -

A. Radar Simulation .... - 10 -

B. LTE Simulation .... - 12 -

C. Radar to LTE Propagation Model .... - 14 -

V. REFERENCES .... - 16 -

I. INTRODUCTION AND SUMMARY

Nokia Networks continues to believe that the 3.5 GHz Band appears well suited to support commercial mobile broadband networks, including although not necessarily limited to small cell deployments. Mobile Network Operators ("MNOs") therefore should be afforded an

[1] Commission Seeks Comment on "In the Matter of Amendment of the Commission's Rules with Regard to Commercial Operations in the 3550-3650 MHz Band", GN Docket No. 12-354, Further Notice of Proposed Rulemaking (*FNPRM*), FCC 14-19, Released: April 23, 2014

opportunity to meaningfully utilize spectrum in this band to enhance mobile broadband coverage and capacity.

Harmonization of the 3.5 GHz allocation with existing global 3rd Generation Partnership Project (3GPP) bands would leverage a growing ecosystem of the Time Division Duplex (TDD) version of Long Term Evolution (LTE) ("TD-LTE") and help achieve economies of scale that should lower costs and reduce time-to-market for equipment and devices. Beyond the band plan, the transmit power and emission limits proposed in the *3.5GHz Small Cells FNPRM* should also align with the 3GPP TD-LTE bands 42 and 43 requirements, especially for the End User Devices if we want the US to leverage the global bands 42 and 43 ecosystems. Nokia Networks also recommends that the proposed maximum conducted output power and maximum Equivalent Isotropic Radiated Power (EIRP), especially for the baseline Citizens Broadband Service Devices (CBSDs) should be at least 6dB higher to be consistent with the 2.4GHz ISM and 5GHz U-NII power levels as defined in the recent Commission's 5GHz Report and Order[2] if power must be summed across all antennas and antenna elements according to the *3.5GHz Small Cells FNPRM*.[3]

A likely prerequisite for wide scale use by MNOs will be some level of guarantees around spectrum availability and usability to maximize new commercial use of this band while protecting certain legacy systems. In particular, Nokia Networks' proposed Authorized/Licensed Shared Access ("ASA/LSA") appears well suited to help meet the market's current and future mobile broadband capacity requirements. In this context, Nokia Networks is pleased to see that the *3.5GHz Small Cells FNPRM* further stresses the expansion of the Priority Access ("PA") tier

[2] ET Docket No. 13-49, Report and Order, Released April 1 2014, "In the Matter of Revision of Part 15 of the Commission's Rules to Permit Unlicensed National Information Infrastructure (U-NII) Devices in the 5 GHz Band"
[3] See Proposed Section 96.38 – General Radio Requirements in *3.5GHz Small Cells FNPRM*

to a broad class of potential users, including MNOs, aligned with the ASA approach. In addition, we also recommend that the Spectrum Access System (SAS) should not configure the network parameters and RF configurations of systems operating in the 3.5 GHz band. This configuration should be left to the Priority Access users, especially MNOs, through the use of a Controller similar to the one that Nokia Networks presented as part of its ASA/LSA proposal. We also caution that the licensing terms for the Priority Access Licenses (PALs) should be closer to the traditional licenses in terms of the geographical coverage and duration of the licenses to make the spectrum more attractive for investments. Moreover, we consider that the GAA floor of 50 percent of available spectrum will similarly not provide enough spectrum to the Priority Access Licensees to encourage them to invest. To further provide the certainty, Nokia Networks continues to advocate the use of a simplified SAS based on LSA. Additionally, Nokia Networks supports expanding the framework to include 3650-3700 MHz to make a total of 150 MHz available.

Numerous commenting parties[4] agree with Nokia Networks that the Exclusion Zones proposed in the *3.5GHz Small Cells FNPRM* and based on National Telecommunications and Information Administration's (NTIA) Fast Track Report[5] should be further studied in details before they are enforced in the Report and Order. In the Public Notice released July 28, 2014[6], the Commission extended the deadline for reply comments in the 3.5 GHz proceeding until

---

[4] *See* Nokia Solutions and Networks US LLC Comments at 5-9 (providing technical analysis); *see also* Alcatel-Lucent Comments at 6-8; AT&T Comments at 34-37; CTIA Comments at 11-13; Ericsson Comments at 10-12; Microsoft Comments at 6-9; Motorola Mobility Comments at 12-15; Motorola Solutions Comments at 9-10; Qualcomm Comments at 7-8 (citing previous analysis); TIA Comments at 4; T-Mobile Comments at 6-8; Verizon Comments at 5-6.

[5] *See* NTIA, An Assessment of the Near-Term Viability of Accommodating Wireless Broadband Systems in the 1675-1710 MHz, 1755-1780 MHz, 3500-3650 MHz, 4200-4220 MHz, and 4380-4400 MHz Bands (rel. October 2010) (NTIA Fast Track Report), available at http://www.ntia.doc.gov/files/ntia/publications/fasttrackevaluation_11152010.pdf.

[6] "WIRELESS TELECOMMUNICATIONS BUREAU EXTENDS PERIOD TO FILE REPLY COMMENTS ON PROPOSED RULES TO ESTABLISH A CITIZENS BROADBAND RADIO SERVICE IN THE 3550-3650 MHz BAND", Released July 28, 2014

August 15, 2014 "*to allow parties to more thoroughly address the complex technical, legal, and policy issues raised in the FNPRM and in the record*." In its initial comments[7], Nokia Networks shared some initial simulation results suggesting that the exclusion zones in the NTIA Fast Track Report, which reached 557 kilometers inland from one type of shipborne radar into a base station located in the Gulf Coast region, are overly conservative. We found out that accurately modeling the radar and LTE systems as well as the propagation characteristics between the radar and LTE systems goes a long way in assessing precisely the interference impact from one system to the other. In the next section, Nokia Networks is pleased to share some further simulation results with the Commission.

II. NOKIA NETWORKS' SIMULATIONS OF RADAR INTERFERENCE TO LTE MACRO AND SMALL CELLS BASE STATIONS SUGGEST THAT THE PROPOSED EXCLUSION ZONES CAN BE FURTHER REDUCED

We show further simulation results hereafter of interference from radar into LTE Base Stations (for both LTE macro cellular and small cells) at various separation distances, again suggesting that commercial LTE macrocells and small cells can operate effectively within the NTIA proposed exclusion zones. The investigation relies on macro cellular and small cells LTE system level simulators based on methodologies used in 3GPP to simulate LTE system performance [1], simulating radar systems with representative parameters from NTIA [2], Free Space Path Loss (FSPL), and Irregular Terrain Model (ITM) propagation [3]. The details about the assumptions and simulations can be found in the Appendix of this document.

[7] *See* Comments of Nokia Solutions and Networks US LLC at 5-9 (filed July 14, 2014).

A. Radar to LTE Macro BSs Interference Simulation Results

First, we look at the macrocell results. As we can see from Figure 1, slight throughput losses incurred when the radar is 50, 100, 150, and 200 km away vis-à-vis the baseline. It is noteworthy that Figure 1 represents relative values.

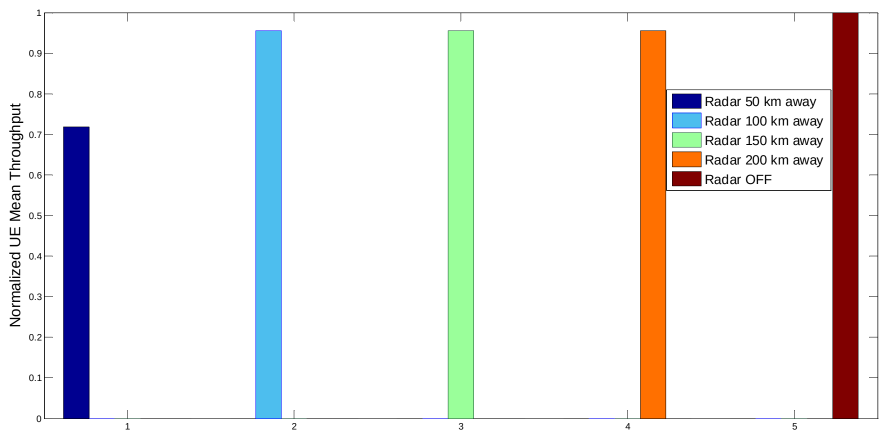

Figure 1: Mean UE throughput at different radar distances to the Macrocell LTE system.

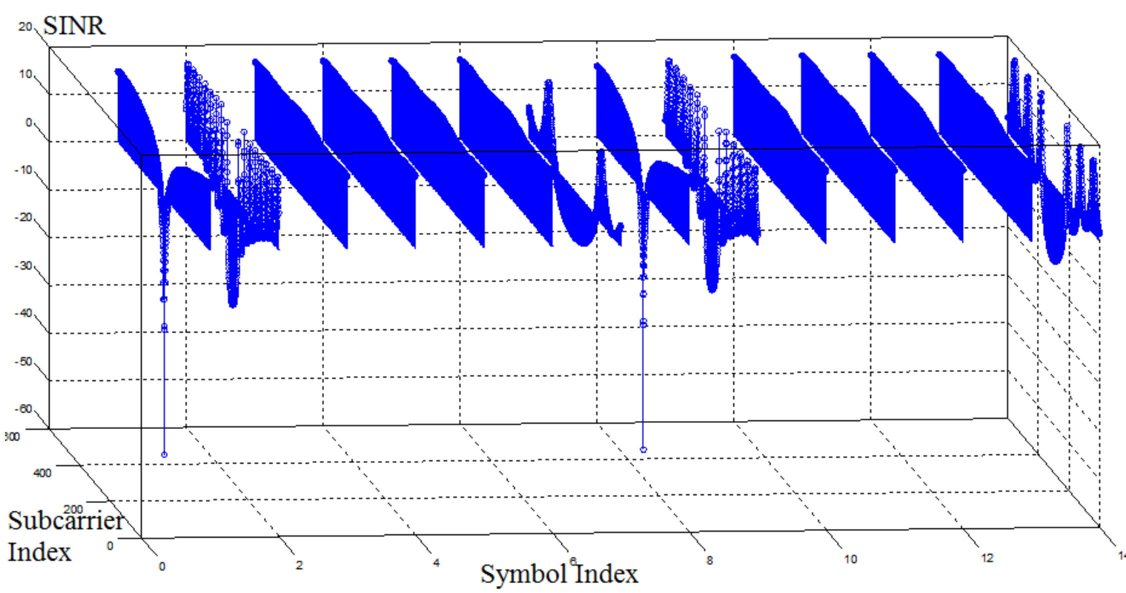

Figure 2: SINR per symbol for the Macro LTE BSs radiated by the radar interference.

We plot the signal-to-interference-to-noise ratio (SINR) of an LTE macro BS versus LTE symbol and subcarrier indices in Figure 2 where we observe an SINR drop due to the radar pulse affecting LTE symbols on the uplink during the simulation time. Interestingly, even when the radar is present, the SINR recovers back to its normal baseline situation until the next pulse hits the same region (same beam position). Because the radar pulse is assumed to be centered in the LTE band, most of the pulse energy is concentrated around subcarrier 300 (in the middle of the LTE band). Also, at 78 μs, the pulse slightly exceeds the duration of the LTE symbol (71.4 μs). Thus, most of the energy is concentrated in symbol 1 and symbol 8, with some remaining pulse energy also present in symbols 2, 9 and 14. This is promising as only certain symbols during an LTE sub-frame are affected by the radar signal.

B. Radar to LTE Small Cells BSs Interference Simulation Results

Next, we explain the results for the small cells. As we can observe from the blue, green and orange bars in Figure 3, when radar is 100, 150, and 200 km away from the LTE system, there is a slight UE throughput decline. As it is expected, the further away the radar, the higher the mean UE throughput as interference becomes less pronounced due to the diffraction loss caused by the ITM in the NLoS region. It is noteworthy that Figure 3 represents relative values. The brown bar represents the baseline, i.e. no radar operates in the vicinity of the cellular system. The investigation for radar distances less than 100 km away from the small cells is currently undergoing.

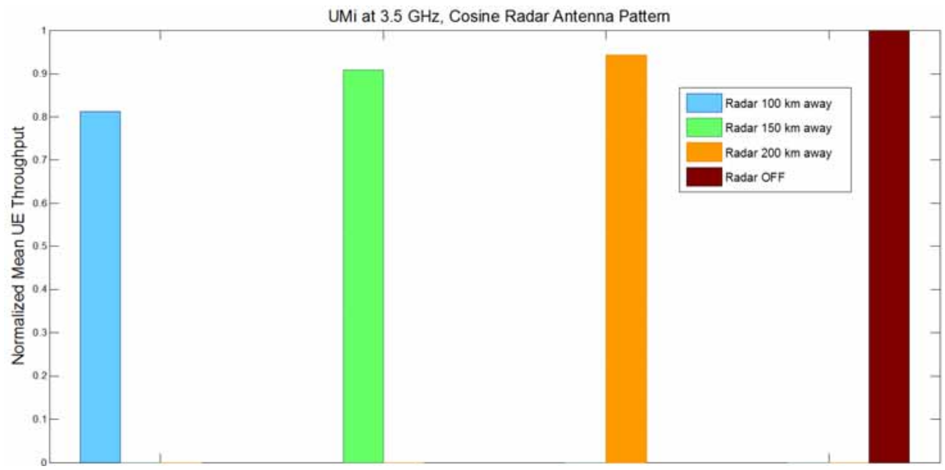

Figure 3: Mean UE throughput at different radar distances to the LTE Small Cells system.

Finally, we plot the SINR of an LTE BS versus LTE symbol for small cells and subcarrier indices in Figure 4 where we observe an SINR drop due to the radar pulse affecting LTE symbols on the uplink during the simulation time. Interestingly, even when the radar is present, the SINR recovers back to its normal baseline situation until the next radiation hits the same region (same beam position). Being 78 μs wide, the pulse exceeds the duration of the LTE symbols (71.4 μs).

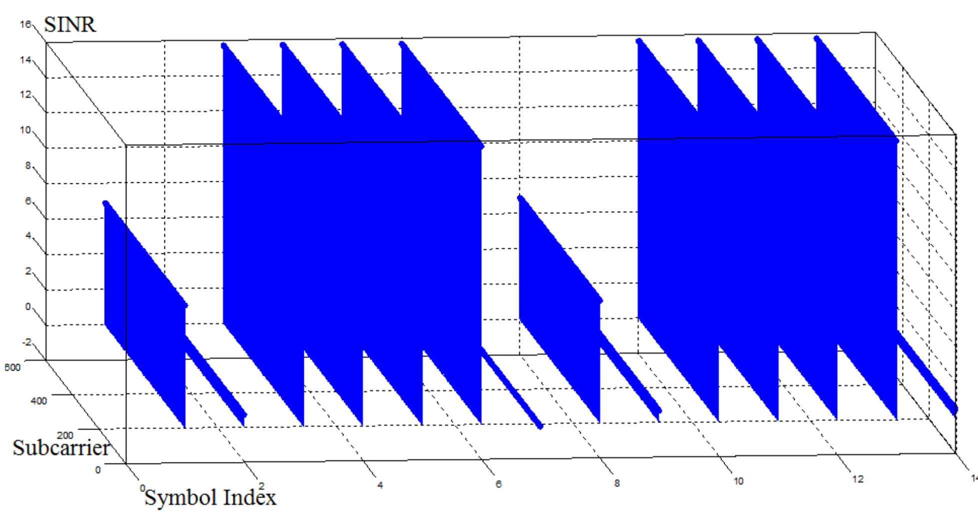

Figure 4: SINR per Symbol for LTE Small Cells radiated by the radar interference.

III. CONCLUSION

Nokia Networks reiterates its view that the 3.5 GHz Band has the potential to enhance mobile broadband networks across the U.S., including through densification of network coverage via small cell deployments. As the Commission continues to receive feedback on its proposals for granting access to this spectrum, Nokia Networks urges the Commission to refine such proposals consistent with an objective of widespread utilization of the band and the development of a sustainable commercial ecosystem as proposed in Nokia Networks' initial comments[8] to this *3.5GHz Small Cells FNPRM* and further developed in these reply comments. Nokia Networks is committed to continuing engaging with the Commission as it moves forward with this critical task.

Respectfully submitted,

Nokia Solutions and Networks US LLC

/s/ *Brian Hendricks*

____

Brian Hendricks
Head of Technology Policy

Prakash Moorut
Spectrum Lead
North America

575 Herndon Parkway
Suite 200
Herndon, VA 20170

August 15, 2014

[8] *See* Comments of Nokia Solutions and Networks US LLC (filed July 14, 2014).

IV. APPENDIX - RADAR TO LTE MACRO AND SMALL CELLS BASE STATIONS INTERFERENCE SIMULATIONS ASSUMPTIONS

We set the simulation time to 5 seconds, during which the impact of the radiation of the radar onto the Base Stations (BSs) of the LTE macro and small cell system is investigated. The radar is co-channel with the LTE system and rotates 360 deg in azimuth in 445 beam positions where the radar sojourns for the dwell time of 4.5 ms and sends 9 pulses 78 µs wide and 83 dBm through its 45 dBi antenna to the BSs. The width of the radiation spans 1.5, 3.0, 4.5, and 6.0 km when the radar is respectively 50, 100, 150, and 200 km away from the LTE system, and all the BSs covered by the radiation could be impacted by interference from the radar pulses, amplified by the radar transmitter and antenna and attenuated by the propagation losses with models presented in section C.

A. Radar Simulation

We leveraged radar operational parameters in Table 1, extracted from NTIA [2]. For items not included in NTIA Fast Track Report [2], due to the sensitive nature of the parameters, we used typical values considering medium-to-large shipborne S-band radars [4] and marked with an asterisk. We place the radar 50, 100, 150, and 200 km away from the LTE system, similar to the scenario in Figure 5 (a), where it radiates into the cellular system depending on the cell radii and radiation diameter *d* which relates to the radar distance *R* from the cellular system (say the base station under interference) and radar horizontal beamwith θ_a as equation (1).

$$d = 2R\tan(\theta_a) \approx 0.03R \tag{1}$$

The radar scans 360 deg in azimuth with an angular speed of 30 rpm, generating a scan time of 2 s. For the macrocellular system and the small cells we leveraged a Pulse Repetition Interval (PRI) of 0.5 ms and 78 µs wide pulses. This means that 4000 pulses (pulse repetition frequency 1/0.5 ms = 2000 Hz) of power 83 dBm, excluding the antenna gain, are emitted during the 2 s antenna scan time. The pulse-widths are 78 µs yielding. Also, the horizontal beamwidth 0.81 deg creates 445 beam positions so that the antenna dwell time becomes 4.5 ms (2s/445). Therefore, BSs affected in each beam position are hit with 9 pulses as in Figure 5 (b), whose abscissa/ordinate is time/amplitude in seconds/Volt where amplitude is the square root of the pulse power in Watts.

Furthermore, the radar antenna was according to the cosine pattern adopted from NTIA's Fast Track evaluation [2], plotted in Figure 6, with the normalized gain as a function of the angle θ from the boresight in equation (2) where the first, second, and third expressions respectively give (i) the theoretical directivity pattern, (ii) a mask equation according to which the pattern deviates from the theoretical one at an angle corresponding to a side lobe of 14.4 dB below the main beam, and (iii) the back lobe.

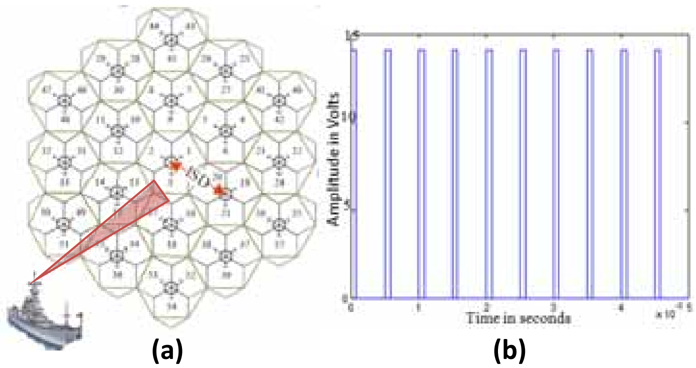

Figure 5: (a) Simulation scenario includes a shipborne radar approaching littoral zones juxtaposed to a 3.5 GHz LTE cellular network. (b) Radar pulses during the antenna dwell time radiating onto LTE

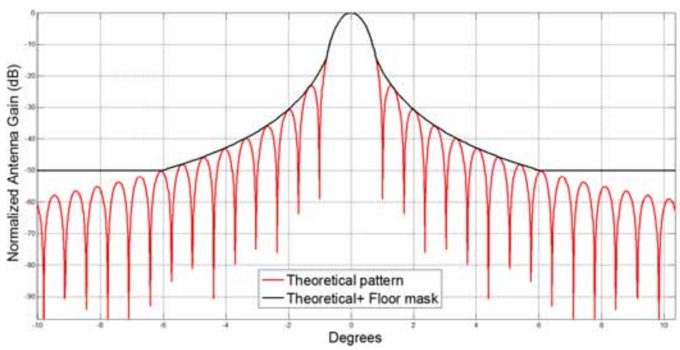

Figure 6: Radar Antenna Pattern: The black curve represents the pattern after the first side lobe is 14.4 dB below the main lobe. The back lobe is constant at -50 dB. The pattern was used in the NTIA Fast Track Report [2].

$$G(\theta) = \begin{cases} \dfrac{\pi}{2}\left(\dfrac{\cos\left(\dfrac{68.8\pi\sin(\theta)}{\theta_{3dB}}\right)}{\left(\dfrac{\pi}{2}\right)^2 - \left(\dfrac{68.8\pi\sin(\theta)}{\theta_{3dB}}\right)^2}\right) \\ -17.51\log_e\left(\dfrac{2.33|\theta|}{\theta_{3dB}}\right) \\ -50\,dB \end{cases} \qquad (2)$$

Table 1: NTIA [2] Radar parameters, except those marked with *, not given in [2], where we used typical parameters (PRI of 0.5 ms and pulse widths of 78 µs).

Parameters	Value
Operating Frequency	3.5 GHz*
Peak Power	83 dBm
Antenna Gain	45 dBi
Antenna Pattern	Cosine
Antenna Height	50 m
Insertion Loss	2 dB
Pulse Repetition Interval	0.5 ms
Pulse-Width	78 µs
Rotation Speed	30 rpm*
Azimuth Beam-Width	0.81 deg*
Elevation Beam-Width	0.81 deg*
Azimuth Scan	360 deg
Distance to LTE	50, 100, 150, 200 km

B. LTE Simulation

The LTE system level simulation is fully compliant with the 3GPP evaluation methodology [1] and is based on the International Telecommunications Union (ITU) recommendations on International Mobile Telecommunications-Advanced (IMT-A) radio interface technologies [5]. It leverages a full-buffer traffic model and includes indoor, small cell and macrocellular infrastructure models. For our simulations, first we considered a macro-cellular model (urban macro) with cell Inter-Site Distance (ISD) of 500 m. All users were simulated at a pedestrian speed of 3 km/h. The network layout contains BSs placed on a grid hexagonally (Figure 5 (a)). Furthermore, we considered a small cell model (urban micro) whose main difference from the macrocells lies in the fact that its BSs are omnidirectional and their antenna heights are smaller than the macrocell case. The antenna heights for macro and small cells in our LTE system were chosen to be respectively 25 and 10 m.

For the macrocells, we deployed 7 sites in the simulation with 120 deg sectors, each with 3 cells. On the other hand, the small cells were not sectorized. The LTE system parameters are illustrated in Table 2, adopted from [5]. It is worth mentioning that user equipment (UE) antennae are omnidirectional. For the macrocells, the BS antenna pattern per sector is as equation (3) in which G_A and θ_A (G_E and θ_E) represent the antenna azimuth (elevation) pattern and angle off the antenna boresight in the azimuth (elevation) direction where $-180^\circ \leq \theta_A \leq 180^\circ$ ($-90^\circ \leq \theta_E \leq 90^\circ$), antenna azimuth (elevation) downtilt is $\theta_{A,t} = 0^\circ$ ($\theta_E = 15^\circ$), A_m = 20 dB is the maximum attenuation, and θ_{3dB} is the antenna 3dB beamwidth. The composite antenna pattern, plotted in Figure 7, can be expressed as in equation (3).

$$G_i(\theta_i) = -\min\{12(\frac{\theta_i - \theta_{i,t}}{\theta_{3dB}})^2, A_m\},\ i \in \{A, E\}$$

$$G = -\min\{-(G_A(\theta_A) + G_E(\theta_E), A_m\} \qquad (3)$$

Table 2: Macrocell and Small Cells LTE Parameters from [1] [5].

Parameters	**Value**
Operating Frequency	3.5 GHz
Layout	Hexagonal grid
Mode	TDD (In each TDD cycle, the uplink traffic ran for 3 ms of on-time, with a 2 ms off-time interval for downlink traffic (DL:UL ratio is 2:3)
Macro/Small Cells BS TX Power	46/30dBm
UE Transmit (TX) Power	23 dBm
Macro-cell sites/cells	7/21 (3 cells per site)
Small cells	84 (4 per macro cell)
Indoor UE for Macro/Small cells	80% / 20%
Bandwidth for Macro / Small cells	20 MHz
Macro/Small cells BS Antenna Gain	17/ 5 dBi
UE Antenna Gain	0 dBi
Inter-site Distance (ISD) for Macro	500 m
Minimum UE-BS Distance for Macro / Small cells	25 / 5 m
BS Antenna Downtilt	12 deg

BS/UE Antenna Height	25/1.5 m
UE Distribution	Uniform
UE Mobility	3 km/h, uniform direction
BS/UE Noise Figure (NF)	5/9 dB
Thermal Noise	-174 dBm/Hz
Service Profile	Full buffer best effort
UE per Cell for Macro / Small cells	10 / 30
Channel Model for Macro / Small cells	UMa / UMi [1]

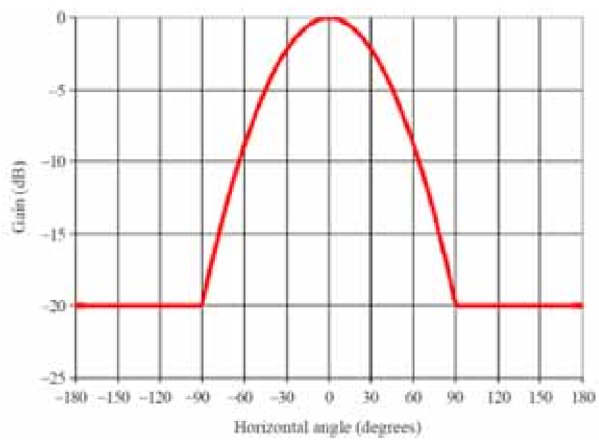

Figure 7: Macrocells: Composite antenna pattern the BSs for 3-sector cells. For small cells, antennae are omnidirectional.

C. Radar to LTE Propagation Model

In order to obtain the radar signal propagation loss from before it reaches the BSs, we need to consider appropriate models based on particularly the distance and terrain between the radar and LTE system. For the LoS region, we use the Free Space Path Loss (FSPL) and for the NLoS region, we leverage the ITM, the predominant model used by the FCC and NTIA as in [2]. FSPL can be expressed using equation (4) in which f is the radar operating frequency in hertz (Table 1), r is the distance in km at which FSPL $L_{dB,FSPL}$ in dB is requested, and r_{LoS} is the border of the LoS region in km as in equation (5) [2] where h_{radar} and h_{LTE} is the radar and LTE antenna height as 50 m and 25 m for macrocells (10 m for small cells).

$$L_{dB,\,FSPL}(r)=20\log(f)+20\log(r)+32.45, r<r_{LoS} \quad (4)$$

$$r_{LoS}=4.1(\sqrt{h_{radar}}+\sqrt{h_{LTE}}) \quad (5)$$

Moreover, we leveraged ITM in its Area Prediction Mode (APM) [3] with the terrain roughness 10 and 20 m, LTE antenna height of 25m (macro), 10m (small cells) and radar antenna height 50 m, ground dielectric constant 15, ground conductivity 0.005 S/m, refractivity 301 N-units, continental temperate climate, and single message mode as listed in Table 3. The plots for the FSPL and ITM diffraction loss are depicted in Figure 8 for the macro and small cells respectively, where the red, blue, and green curves respectively portray the ITM propagation loss for Macrocells, ITM propagation loss for small cells, and FSPL. It is noteworthy that the two models predict very close values for the losses in the LoS region, approximately 50 km, whereas this loss sharply elevates in the NLoS region, where ITM model is valid. Loosely speaking, we can take the envelope of the plotted curves as the amount of propagation loss that the radar wave undergoes before it reaches the LTE BSs.

Table 3: ITM Parameters for Macro and Small Cells.

Parameters	Value
Operation Mode	Area Prediction Mode
Macro, Small cells LTE/Radar Antenna Height	25, 10/50 m
Dielectric Constant	15
Conductivity	0.005 S/m
Refractivity	301 N-units
Climate	Continental Temperate
Variability Mode	Single Message

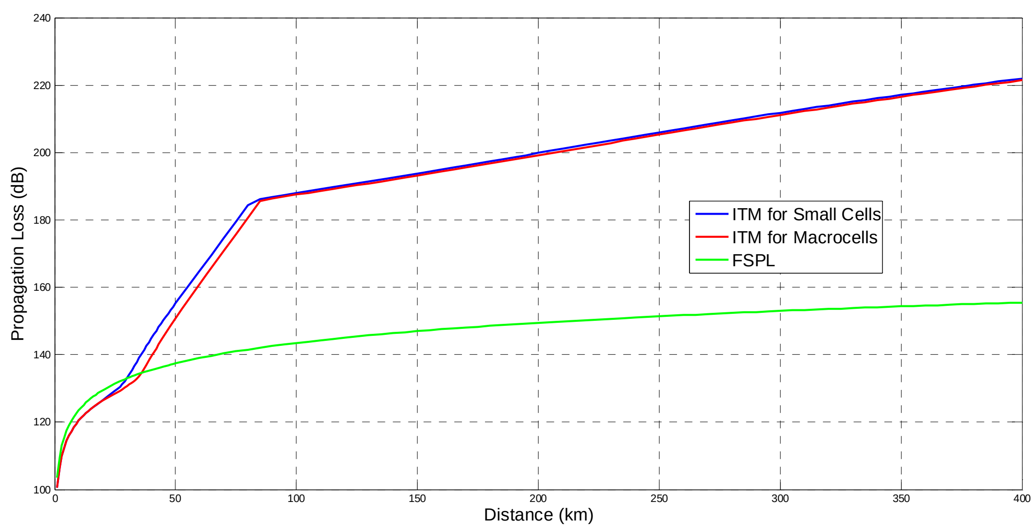

Figure 8: FSPL and ITM for macrocells and small cells.

V. REFERENCES

[1] 3GPP TR 36.814 V9.0.0 (2010-03), “Further advancements for E-UTRA physical layer aspects”, Release 9.

[2] “An Assessment of the Near-Term Viability of Accommodating Wireless Broadband Systems in the 1675-1710 MHz, 1755-1780 MHz, 3500-3650 MHz, 4200-4220 MHz and 4380-4400 MHz Bands” NTIA, U.S. Dept. of Commerce, Nov. 2010

[3] G. Hufford, A. Longley, W. Kissick, “A Guide to the Use of the ITS Irregular Terrain Model in the Area Prediction Mode”, U.S. Dept. of Commerce, 1982.

[4] M. Richards, J. Scheer, W. Holm, “Principles of Modern Radar”, SciTech Publishing, 2010.

[5] “Guidelines for Evaluation of Radio Interface Technologies for IMT-Advanced”, ITU-R M.2135-1, Dec. 2009